Associations between Physical Activity Behaviours and Learning Outcomes in Students Attending Vocational Education and Training.

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Associations between Physical Activity Behaviours and Learning Outcomes in Students Attending Vocational Education and Training

Associaties tussen Fysiek Actief Gedrag en Leeruitkomsten bij Studenten in het Middelbaar Beroeps Onderwijs

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Index

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Summary

Background: Physical activity (PA) declines by an estimated 7% per year through adolescence (Dumith, Gigante, Domingues, & Kohl, 2011) and there is a concurrent increase in sedentary behaviour (SB) with a mean increase of 90 minutes per day sitting from early to middle adolescence (10-16 years old; Mitchell et al., 2012). Similar worrying trends are being reported in the Netherlands where students attending vocational education and training (VET) spend up to 700 hours a year in classrooms (Rijksoverheid, n.d.) and their activity levels are relatively low (Rijpstra & Bernaards, 2011). This may have an effect on school performance and executive functioning, as shown in studies on children (Crova et al., 2014; Singh et al., 2018). Hardly any research has been done on this subject among VET students, an age category of which it is known that the brain is still developing.

Aim: This study is part of the PHIT2LEARN research project and the aim was to investigate what the association is between physical activity behaviours and learning outcomes in students attending VET.

Participants, procedure and design: An observational cross-sectional study was designed, in which 29 Dutch VET students (≈ 16-18 years old; in the first or second year of a level 2 curriculum) participated.

Measures: Physical activity behaviours were measured at baseline with an accelerometer (ActivPAL3) objectively measuring sedentary behaviour, light physical activity, moderate-to-vigorous physical activity, and sit-stand transitions for 24 hours a day during one week. Learning outcomes were operationalized as school performance (SP) (tested by an AMN Mathematics Test) and executive functioning (EF) (tested by the Trail Making Test, Digit Span Backward test, and Colour-Shape Task). Data were analysed with (bivariate) correlation analyses and multiple regression analyses using SPSS (version 24).

Results: No significant associations between any of the PAB measures and any of the SP were found, even after correcting for sex and BMI. Also, no significant associations between any of the PAB measures and any of the EF measures were found, even after correcting for sex and BMI.

Conclusion: In summary, VET schools should not bet everything on physical activity, because the evidence of an association between physical activity behaviours and learning outcomes in VET students is not yet sufficient. However, VET students are the employees of the future who will need to be educated towards vital citizenship (Ministerie van Onderwijs, Cultuur en Wetenschap, 2019).

Creating awareness about the risks of sedentary behaviour and the opportunities for physical activity should start early.

Keywords: sedentary behaviour, (light and moderate-to-vigorous) physical activity, sit-stand transitions, physical activity behaviours, learning outcomes, school performance, executive functioning, students, adolescence, vocational education and training (VET)

Associaties tussen Fysiek Actief Gedrag en Leeruitkomsten bij Studenten in het Middelbaar Beroeps Onderwijs

G.A. Groenewoudt

Samenvatting

Achtergrond: Fysieke activiteit daalt met naar schatting 7% per jaar gedurende de adolescentie (Dumith, Gigante, Domingues, & Kohl, 2011) en er is een gelijktijdige toename van sedentair gedrag, met een gemiddelde toename van 90 minuten zitgedrag per dag van de vroege tot midden adolescentie (10-16 jaar; Mitchell et al., 2012). Soortgelijke zorgwekkende trends worden gemeld in Nederland, waar studenten in het middelbaar beroepsonderwijs (mbo) tot 700 uur per jaar in klaslokalen doorbrengen (Rijksoverheid, n.d.) en hun activiteitenniveau relatief laag is (Rijpstra & Bernaards, 2011). Dit kan een effect hebben op de schoolprestaties en het executief functioneren, zoals blijkt uit studies onder kinderen (Crova et al., 2014; Singh et al., 2018). Bij mbo-studenten, een leeftijdscategorie waarvan bekend is dat het brein nog volop in ontwikkeling is, is nauwelijks onderzoek hiernaar gedaan.

Doel: Deze studie maakt deel uit van het PHIT2LEARN-onderzoeksproject en had als doel te onderzoeken wat de associaties zijn tussen fysiek actief gedrag en leeruitkomsten bij studenten in het mbo.

Deelnemers, procedure en onderzoekontwerp: Er is een observationele cross-sectionele studie uitgevoerd, waaraan 29 Nederlandse mbo-studenten (≈ 16-18 jaar; in het eerste of tweede jaar van een niveau 2-curriculum) deelnamen.

Meetinstrumenten: Fysieke activiteit werd in kaart gebracht met een beweegsensor (ActivPAL3) die objectief het sedentair gedrag, lichte fysieke activiteit, matig-tot-intensieve fysieke activiteit en zit-sta transities gedurende een week kan meten. De leeruitkomsten werden geoperationaliseerd als schoolprestaties (SP) (getest door een AMN-wiskundetoets) en executief functioneren (EF) (getest door de Trail Making Test, Digit Span Backward test, en Colour-Shape Task). De gegevens zijn geanalyseerd met (bivariate) correlatieanalyses en meervoudige regressieanalyses met behulp van SPSS (versie 24).

Resultaten: Er zijn geen significante associaties gevonden tussen een van de fysieke activiteitsmaten en een van de SP-maten, zelfs niet na correctie voor geslacht en BMI. Ook zijn er geen significante associaties gevonden tussen de fysieke activiteitsmaten en een van de EF-maten, zelfs niet na correctie voor geslacht en BMI.

Conclusie: Samenvattend kan worden gesteld dat mbo-scholen niet alles moeten inzetten op lichaamsbeweging, omdat het bewijs van een verband tussen fysieke activiteit en leerresultaten bij mbo-studenten nog niet voldoende is aangetoond. Mbo-studenten zijn echter wel de werknemers van de toekomst die moeten worden opgeleid tot vitaal burgerschap (Ministerie van Onderwijs, Cultuur en Wetenschap, 2019). Het creëren van bewustzijn over de risico's van sedentair gedrag en de mogelijkheden voor lichaamsbeweging moet daarom wel vroeg beginnen.

Sleutelwoorden: sedentair gedrag, (lichte en matig-tot-intensieve) fysieke activiteit, zit-sta transities, fysiek actief gedrag, leeruitkomsten, schoolprestaties, executief functioneren, studenten, adolescentie, middelbaar beroeps onderwijs (mbo)

Introduction

Problem definition

There are concerns with respect to adolescent's inactivity. Physical activity (PA) declines by an estimated 7% per year through adolescence (Dumith, Gigante, Domingues, & Kohl, 2011) and there is a concurrent increase in sedentary behaviour (SB) with a mean increase of 90 minutes per day sitting from early to late adolescence (Mitchell et al., 2012). The increase of SB and decline of PA in adolescence and the potential negative impact of SB on brain maturation during this sensitive period (Dahl, 2003) may have an effect on school performance and executive functioning. Singh et al. (2018) found strong evidence for beneficial effects of PA on mathematics performance in children in primary education. Crova et al. (2014) found that improvement in inhibition (Miyake et al., 2000) after an enhanced physical education programme was more obvious in overweight children than in lean children (9-10 years old).

The relation of sedentary behaviour and physical activity on school performance and executive functioning within the next phase of the educational system is an unexplored area. Within this area, research should aim for schools of lower socio-economic status, as this is a key demographic for improving academic achievement (Sherry, Pearson, & Clemes, 2016). These findings make school for vocational education and training (VET) and its classrooms a relevant research environment. This relevance is enhanced by the fact that over 40% of all Dutch adolescents (≈ 15-20 years old) are enrolled in VET (Centraal Bureau voor Statistiek, 2018), where they spend up to 700 hours per year in classrooms (Rijksoverheid, n.d.). Besides, VET student activity levels are relatively low (Rijpstra & Bernaards, 2011). Therefore, the aim of this study is to investigate the association between physical activity behaviours (PAB) and learning outcomes (school performance and executive functioning) in students attending vocational education and training (VET).

Theoretical framework

Physical activity behaviours in adolescence

Sedentary behaviour (SB) has been defined as "any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" (Bames et al., 2012, p. 540). The metabolic equivalent of task (MET) is defined as the amount of oxygen consumed while sitting at rest (Jette, Sidney, & Blümchen, 1990). Acts of sedentary behaviour (SB) such as watching TV, using the internet and playing computer games have become favoured forms of passive entertainment amongst youth (Rideout, Foehr, & Roberts, 2010). SB should be limited to less than two hours per day outside of school. This standard is established by the American Academy of Pediatrics (2001), the National Association for Sport and Physical Education (2004) and is adopted by the Netherlands Organisation for Applied Scientific Research (TNO). The percentage of VET students who meet the norm for SB does not differ between men and women but between age groups. However, this difference between age groups is very small (Rijpstra & Bernaards, 2011).

SB is not the same as inadequate physical activity, and guidelines differ. Physical activity can be performed in a variety of intensities (i.e., behaviours), ranging between light, moderate, and vigorous intensity activity. Light intensity physical activities require the least amount of effort, compared to moderate and vigorous activities (LPA; <3 MET; e.g., sleeping, watching TV, writing, typing, and walking (up to 4 km/h)). Moderate intensity physical activities require more oxygen consumption than light activities (MPA; 3-6 METs; e.g., brisk walking, active involvement in games). Vigorous intensity physical activities require the highest amount of oxygen consumption (VPA; >6 METs; e.g., running, cycling, competitive sports and games). Children and youth (5-17 years old) should do at least 60 minutes of MPA to VPA daily. Adults (18-64 years old) should do at least 150 minutes of MPA or 75 minutes of VPA throughout the week (World Health Organization, 2010). These guidelines correspond to the Dutch variant (in Dutch ‘Nederlandse Norm Gezond Bewegen (NNGB)’; Kemper, Ooijendijk, & Stiggelbout, 2004). However, even for those who meet these guidelines, there is still a significant part of their time left for SB. This means that individuals can be classified as both active and sedentary (Thivel et al., 2018).

Physical activity in adolescence declines by an estimated 7% per year (Dumith et al., 2011). On the other hand, there is a concurrent increase in sedentary time, with a mean increase of 90 minutes per day sitting from early to late adolescence (Mitchell et al., 2012). At last, adolescents report nearly 10 hours per day of total SB, with nearly 8 hours attributed to screen time (Rideout et al., 2010). Similar trends are being reported in the Netherlands where VET students spend up to 700 hours a year in classrooms (Rijksoverheid, n.d.) and their activity levels are relatively low (Rijpstra & Bernaards, 2011). Furthermore, around a third of the VET students watch TV (32%) and use the computer (39%) for at least 2 hours per day outside of school. Altogether, 80% of VET students spent at least 2 hours per day outside of school sitting behind the TV or computer and therefore do not meet the two-hour limit for SB. Male students meet the above-mentioned NNGB standard more often than female students (Rijpstra & Bernaards, 2011).

SB is associated with a variety of health- and learning problems. First of all, there is an increased risk of cardio-metabolic diseases, and even all-cause mortality (Katzmarzyk, Church, Craig, & Bouchard, 2009; Owen, Bauman, & Brown, 2009). More importantly, there is a large body of evidence which suggests that decreasing the time spent sitting is associated with lower health risk in youth aged 5-17 years (Tremblay et al., 2011). Second of all, adolescence is a ‘sensitive period’ for the human brain, when particular parts and their corresponding functions are especially susceptible to environmental influences (Huttenlocher, 2002). During the transition from childhood into adulthood, the volume of grey matter in the prefrontal cortex peaks and a substantial reorganization of the prefrontal cortex systems occurs (Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Giedd et al., 1999). This allows for enhanced ability to solve problems, multitasking, and the capability to process complex information (Giedd et al., 1999). However, a sedentary lifestyle as well as trauma, drug abuse and chronic stress may have a negative impact on brain maturation during this sensitive period (Arain et al., 2013).

Encouraging appropriate SB habits might benefit adolescents on the long-term, as SB habits formed early in life may track over time (Janz, Burns, & Levy, 2005). Given the fact that VET students spend a considerable amount of time in classrooms (Rijksoverheid, n.d.), VET schools present an ideal research environment for reducing SB in adolescents.

School performance and executive functioning in vocational education and training

Around 40% of all Dutch adolescents are enrolled in VET schools (in Dutch ‘middelbaar beroepsonderwijs’; MBO) and approximately 40% of the Dutch working population has obtained a VET qualification (Centraal Bureau voor Statistiek, 2018). VET courses, contrary to other educational levels, have been developed with the specific goal of preparing students for direct introduction in the labour market. There are two learning pathways in VET with durations from 6 months to 4 years: the work-based option, offering a combination of study and work (in Dutch ‘Beroeps Begeleidende Leerweg’; BBL), and the school-based pathway with full-time education and short internships (in Dutch ‘Beroeps Opleidende Leerweg’; BOL). In both BLL and BOL, students gain work experience in recognized internship companies (MBO Raad, 2018). The requirements that students must meet to obtain a certificate are described in a qualification file. In the first place, students must take exams for Dutch, mathematics, career and citizenship, and English (only in level 4). These knowledge-based aspects of ability and learning will be referred to as *school performance* (SP). In the second place, students must pass practical exams to demonstrate their skills (MBO Raad, n.d.).

Furthermore, in a learning environment, such as VET schools, students are expected to attend to a teacher, follow rules, concentrate on a task, and suppress counterproductive impulses. These skills are equally as important as SP as they allow students to acquire content knowledge more easily (Zelazo, Blair, & Willoughby, 2016). When successful in these tasks, students are exhibiting high *executive functions* (EF) (Diamond, 2013).

EF are generally characterized as a specific set of attention-regulations skills that are needed to control and regulate goal-directed thought and action (Diamond, 2013). Since EF are supported by the prefrontal cortex, that peaks and substantially reorganizes during the transition from childhood into adulthood, these skills mature well into late adolescence (Bull et al., 2011; Giedd et al., 1999). Miyake et al. (2000) propose three aspects of EF: shifting, updating, and inhibition. The first aspect concerns *shifting* back and forth between multiple tasks, mental sets or operations. The second aspect, *updating*, requires monitoring and coding the relevance of incoming information and then appropriately revising the items held in the working memory. The third aspect concerns someone's ability to deliberately *inhibit* dominant, automatic, or prepotent responses when necessary (Miyake et al., 2000). Like other skills, these EF skills are obtained largely as a function of practice or experience. The repeated use strengthens them, increases the efficiency of the corresponding neural circuitry, and the probability that they will be activated in the future (Zelazo et al., 2016). Even more, evidence was found that EF can be used as a predictor for SP (Best, Miller, & Naglieri, 2011; Duckworth & Seligman, 2005; Latzman, Elkovitch, Young, & Clark, 2010; Samuels, Tournaki, Blackman, & Zilinski, 2016).

Research aimed at understanding the childhood socioeconomic status (SES) achievement gap has found that EF predicts academic achievement (Best et al., 2011). EF contributes to the prediction of SP (e.g., reading, mathematics, science) in 11 to 16-year-old males. Specifically, (1) conceptual flexibility, which is highly similar to Miyake et al.'s (2000) *shifting*, is a significant contributor in explaining reading and science, and (2) inhibition produces significant main effects for mathematics and science (Latzman et al, 2010). This is confirmed by Samuels, Tournaki, Blackman, and Zilinski (2016) who found that EF scores in middle and early high school students (12-15 years old) can predict academic performance in several subsequent annual grade point averages (GPAs) (e.g., in English, mathematics) (Samuels et al., 2016). Besides, a study on grade 8 students (≈ 13.4 years old) shows that students with high self-discipline, a behaviour that implies the exercise of EF skills but is not the same, outperform their more impulsive classmates on academic performance, including marks and standardized achievement-test scores. Self-discipline predicts even more variance in these academic outcomes than did IQ (Duckworth & Seligman, 2005).

The association between physical activity behaviours and school performance or executive functioning

The increase of SB and decline of PA in adolescence (Dumith et al., 2011; Mitchell et al., 2012; Rideout et al., 2010), and the negative impact of SB on brain maturation during this sensitive period (Dahl, 2003) may have an effect on SP and EF. Studies in pre- and early adolescence and of other educational levels are included in describing this evolving research domain. A systematic review from Carson et al. (2016) on children and youth aged 5-17 years, indicates that SB inside and outside school may have a different impact on academic achievement. When focusing on longitudinal studies, higher duration of watching TV was found to be significantly associated with lower reading and mathematics achievement (Bowers & Berland, 2013; Romer, Bagdasarov, & More, 2013; Sharif, Wills, & Sargent, 2010). On the other hand, higher durations of sitting down reading and doing homework outside of school were significantly associated with higher academic achievement (Bowers & Berland, 2013; Romer et al, 2013). No studies in this review presented exposure categories (i.e., duration, patterns, and types of SB), making it difficult to draw conclusions regarding the amount of SB (Carson et al., 2016).

Not only SB, but also other PAB may have an effect on SP. By means of a systematic review Singh et al. (2018) found inconclusive evidence for the beneficial effects of physical activity (PA) interventions on overall academic performance in children in primary education. However, strong evidence was found for beneficial effects of PA (mainly MVPA) on mathematics performance.

An area of research in its infancy is that concerning the use of standing desks. These discourage SB and promote shifting between sitting and standing, and LPA in classrooms. A few exploratory reviews and pilot studies indicate that the use of standings desks affects academic outcomes (Hinckson et al., 2016; Minges et al., 2016; Sherry et al., 2016). It should be noted that, due to the fact that this area of research is still young, samples are usually small, and not all studies address the same SP and EF variables. A pilot study (N = 8) with sixth-graders (≈ 11.3 years old) reported an improvement in classroom behaviour after integrating standing desks, in terms of classroom management, student concentration in academic materials, and student discomfort, but these findings were not statistically significant (Koepp et al., 2012). Inattention and hyperactivity-impulsivity were examined in a study (N = 26) where a 'dynamic classroom' environment was conducted. Children's (≈ 9.8 years old) overall sitting time reduced by implementing height-appropriate workstations. Although the intervention group showed a greater reduction on inattention and hyperactivity-impulsivity, there were no significant differences in the final measurement (Aminian, Hinckson, & Stewart, 2015). At last, one study (N = 282) found that standing desks when used in elementary classrooms (grade 2-4) do not seem to result in adverse effects on academic engagement (e.g., answering a question, raising a hand) (Dornhecker, Blake, Benden, Zhao, & Wendel, 2015). This suggests that standing desks can be introduced in the classroom to combat SB without adverse effects on academic engagement.

Research on the effect of PAB on EF in adolescence (≈ 15-20 years old) is limited. Wickel (2017) examined youth (15 years old; N = 403) with a daily proportion of sedentary time of 60%. Inhibition, working memory (i.e., updating), and fluid intelligence (i.e., shifting) were significantly positively associated with sedentary time (B = .003, .055, and .045, respectively). Working memory was inversely associated with each PA intensity (Adjusted B coefficients ranged from -.051 to -.266 across PA intensities) ($p \leq .01$ for each coefficient), while fluid intelligence was negatively related to LPA (B = -.055; $p \leq .001$). Inhibition was inversely associated with LPA within the combined sample (B = -.003; $p \leq .001$), and inversely related with MPA and MVPA specifically among boys (B_{boys} = -.014 and -.008, respectively) ($p \leq .05$ for each coefficient). There is more evidence for the association between PAB and EF in children (De Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Diamond & Lee, 2011; Fedewa & Ahn, 2011; Tomporowski, Davis, Miller, & Naglieri, 2008). Crova et al. (2014) found better inhibition in higher- than lower-fit children (9-10 years old). They also found that improvement in inhibition after an enhanced physical education programme was more obvious in overweight children (BMI >25) than in lean children. Aerobic fitness gains were no mediator in such interaction effects.

In conclusion, there are some aspects of importance in follow-up research into the associations between PAB and learning outcomes. First of all, standardised measures on school performance (e.g., standardised test scores) and cognitive ability (e.g., executive functioning) are essential for this research area to progress (Hinckson et al., 2016; Singh et al., 2018). Second, PAB characteristics should be specified and underlying moderators (e.g., gender and BMI) should be included in research (Singh et al., 2018). Third, additional research should aim for schools of lower socio-economic status as this is a key demographic for improving academic achievement (Sherry et al., 2016). Fourth, research is mainly aimed at school aged children (5-18 years old), therefore research is needed within the next phase of the educational system (Sherry et al., 2016). This makes VET schools an ideal research environment. Especially, as over 40% of all Dutch adolescents are enrolled in VET (Centraal Bureau voor Statistiek, 2018).

Research question and hypotheses

This study was part of the PHIT2LEARN research project, which is short for PHysical activity InTerventions to enhance LEARNing in vocational education and training. The goal of this overarching research project is investigating causal effects of PA/SB interventions on a variety of learning performance measures in VET students. In that context, the current study examined the following research question: ‘What is the association between physical activity behaviours and learning outcomes in students attending vocational education and training (VET)?’, This can be subdivided in the following sub-questions:

Q1 What is the association between PAB and school performance in VET students, after correction for covariates?

Q2 What is the association between PAB and executive functioning in VET students, after correction for covariates?

Based on findings in the theoretical framework this led to the following hypotheses:

H1 The amount of PAB is associated with school performance in VET students, specifically a positive association is expected for the amount of MVPA and school performance.

H2 The amount of PAB is associated with executive functioning in VET students, specifically positive associations are expected between the amount of SB and executive functioning, and negative associations are expected between the amount of

LPA and MVPA and updating (EF subdomain), and the amount of LPA and shifting and inhibition (both EF subdomains).

Figure 1. Conceptual model with independent (Physical Activity Behaviours) and dependent (school performance and executive functioning) variables.

Methods

Design

The current study is part of the PHIT2Learn study (4b), a cluster randomised controlled trial on the effects of a sit-stand desk intervention on school performance and executive functioning. To answer the current research question only data from the baseline measurement were used, resulting in an exploratory cross-sectional study. PAB data from a selected sample population of all Dutch VET students (level 2), at baseline were analysed and associated with learning outcome measures, operationalized as school performance and executive functioning, determined at the same moment in time.

Participants

This study was carried out within three Dutch regional educational centres for vocational education and training. Participants (≈ 16-18 years old; middle/late adolescents) had to be in the first or second (i.e., last) year of a level 2 curriculum for financial administration employee or ICT support technician (BOL). Both curricula provide a predominantly sedentary educational setting and educate them towards mainly sedentary jobs, and thus the largest effect of a standing intervention of the main/overarching study could be expected here. Participants were recruited among ten classes (four classes in school A, four classes in school B, and two classes in school C) of these educational centres. An a priori power analysis using G*Power (version 3.1.9.4.) was conducted to estimate a sufficient sample size for a linear multiple regression (F test: fixed model, R^2 increase, with three out of six tested predictors) to achieve adequate power. No effect sizes were reported in studies on the associations between LPA, MVPA, sit-stand transitions, school performance, and executive functioning in adolescents, therefore a small effect size was chosen. With f^2 = 0.2, power at 80%, and alpha at 0.05, a total sample size of 59 was needed.

Measures

Independent variables

PAB were measured objectively using an *accelerometer* (ActivPAL3^{TM}; PAL Technologies Ltd, Glasgow, UK). This small lightweight (15g.) electronic logger with three measurement axes was attached to the participants thigh for seven consecutive days. Each valid day started at midnight and lasted 24 hours. It summarized data in 20 second intervals. PAB is operationalized as sedentary behaviour (SB), light physical activity (LPA), moderate-to-vigorous physical activity (MVPA), and sit-stand transitions. Average sitting time (in minutes) for valid days in the recording was classified as SB. Average standing time (in minutes) and total stepping time (in minutes) minus stepping time (in minutes; cadence ≥100; 100 steps/minute), including slow cycling, for valid days in the recording were classified as LPA. Stepping time (cadence ≥100; 100 steps/minute), including medium to fast cycling, was classified as MVPA. This categorisation is based on the assumption that a cadence of 100 steps/minute represents a reasonable minimum level for MVPA (Dall, McCrorie, Granat, & Stansfield, 2013). A transition from sitting to standing and vice versa for valid days in the recording was classified as one sit-to-stand transition. The ActivPAL has been assessed to be a valid and reliable instrument to measure physical activity in adolescents (Dowd, Harrington, & Donnelly, 2012) and adults (Dahlgren, Carlsson, Moorhead, Häger-Ross, & McDonough, 2010).

Dependent variables

Outcome measures were classified in two categories, namely school performance (SP) and executive functioning (EF).

SP was tested by a standardized computerized *mathematics test* (MT; AMN, 2010). This test contained 39 items on 1F/2F level. To prevent cheating, items were randomized per participant. The test usually takes about 30 minutes, but the response time was extended to 60 minutes because a short instruction was included, and the first-year students did not yet master the 2F level that is required at the end of their education (MBO Raad, n.d.). The test was conducted via an online system where students could skip items and return to them later. The content domains in this test were numbers (11 items), proportions (12 items), measurement & geometry (7 items), and relations (tables, diagrams, graphs) (9 items). All domains were tested on three subdomains: notation and meaning (a), making connections (b) and applying knowledge (c). Whether a participant skipped an item (0 = no, 1 = yes) and the score for each item that was answered (0 = incorrect, 1 = correct), was registered. The scores on all four content domains were calculated by summing up all correct answers from the three subdomains. The total score (up to 39) was measured by the number of correct answers on all four content domains. The items were obtained from an AMN mathematics test (with 80 items) with an excellent reliability (> .90).

EF can according to Miyake et al. (2000) be subdivided in the three domains: shifting, updating and inhibition. In accordance with this classification three tests were used. A computerized version (Millisecond Software, LLC) of the *Trail Making Test* (TMT; Reitan, 1958) was used to measure several different cognitive constructs, including (set-)‘shifting’. The test consists of two parts in which the participant is instructed to connect a set of 25 dots spread across the computer screen. In Part A (TMT-A), the dots are numbered (1-25), and the participant should draw a line to connect the numbers in ascending order. In Part B (TMT-B), the dots include both numbers (1-13) and letters (A-L). As in Part A, the participant draws a line to connect the dots in ascending order, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C-4-D …. L-13). Figure 2 shows sample items of Part A and B. The participant was instructed to connect the dots as quickly as possible, while still maintaining accuracy, and without having to let go of the trackpad of the laptop. Reaction time (RTs; in milliseconds) was recorded and stopped when the participants had connected the right dots. If errors were made it was reflected in the completion time. Before the official measurement started, a practice round was required. Research on construct validity shows that TMT-A requires mainly visuo-perceptual abilities, while TMT-B primarily reflects working memory and secondarily task-switching ability (Sánchez-Cubillo et al., 2009). The RT to complete Part A (TMT-A) was used to measure trail making latency. The derived score of the difference in RT to complete both parts (TMT-B score minus TMT-A score) was used as indicator of (set-) shifting (Arbuthnott & Frank, 2000). Test-retest reliability on a paper and pencil version (for intervals of 3 weeks to 1 year) is moderate to high for Part A (r = .36 – .79) and Part B (r = .44 – .89) (Dikmen, Heaton, Grant, & Temkin, 1999).

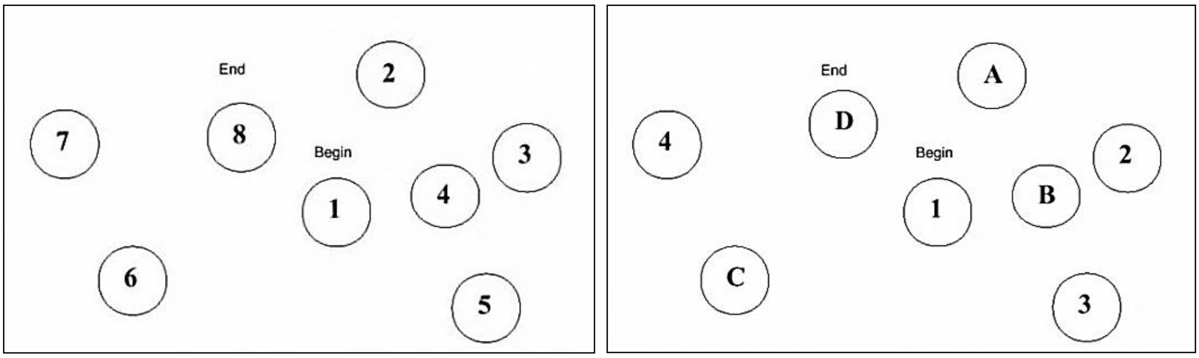

Figure 2. Sample items of TMT Part A (left) and Part B (right).

A paper version of the subtest *Digit Span Backward* test (DSB) from the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1958) was used to measure the ability to ‘update’ the working memory. Participants heard a sequence of numbers beginning with two digits (e.g., '5, 2) and were tasked to immediately write down the sequence in reversed order, with increasingly longer sequences being tested in each trial (e.g., '6, 2, 0'). Before the official measurement started, a practice trial of two digits was required. Testing stopped when a participant made two equal consecutive errors or when the maximum length of 8 digits was reached. The longest sequence that could accurately be remembered (from 2 up to 8 digits), was used as the outcome measure for updating (e.g., 7 digits is score '7'). DSB reliability is reported as part of the standardization for the WAIS-IV test, that is administered individually. The average reliability coefficients for all subtest scores range from acceptable (.78) to excellent (≥.90). Overall results indicate that the WAIS-IV has acceptable test-rest reliability (with a mean interval between testing of 22 days) for each of the four age bands (16-29, 30-54, 55-69, and 70-90). Subtest stability coefficients range from adequate (*r* = .74) to excellent (*r* = .90), with a majority of good scores (*r* = .80s) (Climie & Rostad, 2011).

A modified version (Millisecond Software, LLC) of the *Colour-Shape Task* (CST; Miyake, Emerson, Padilla, & Ahn, 2004, Miyake & Friedman, 2012) was used to assess someone's ability to deliberately 'inhibit' dominant, automatic, or prepotent responses. In this task participants were presented with four rounds, that consisted of 16 training trials and subsequently 64 test trials. Each round was preceded by a cue indicating what characteristic (shape or colour) to focus on, before participants were presented with shapes, colours or combinations of both. All stimuli were presented on a laptop screen until an answer was entered by using the index fingers (pressing 'A' for circle and red, and 'L' for triangle and green). Figure 3 shows a visual representation of all CST rounds. In round one (shape-test), participants were presented with shapes and answered whether they saw a circle or a triangle. In round two (colour-test) participants were presented with colours and answered whether they saw a green or a red colour patch. In round three (shape-inhibition-task) and four (colour-inhibition-task), shapes placed on colour patches were presented (e.g., a circle on a green patch). Participants answered with a shape (round three) or colour (round four), regardless of the distracting stimulus (colour patch). For all rounds, reaction times (RTs; in milliseconds) and correctness of the answers were recorded. RTs was only based on correct trials. The mean RT to complete at least two of the four test rounds was used to measure stimulus-reaction latency. Inhibition cost was calculated by subtracting the mean RT in round one and two from the mean RT in round three and four, which are both inhibition tasks. No studies were found on CST validity and reliability.

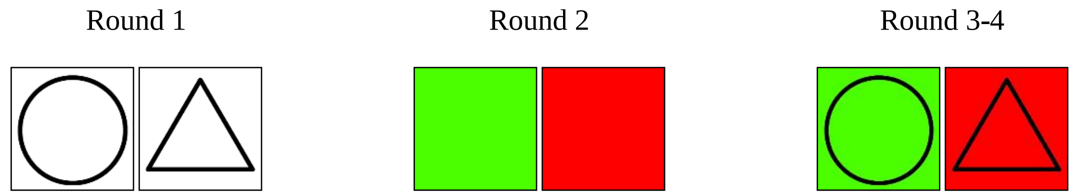

Figure 3. A visual representation of all CST rounds. Round 1 with one stimulus, focus on shape. Round 2 with one stimulus, with focus on colour. Round 3-4 with two stimuli, focus on shape (round 3) or colour (round 4) with distracting colour patch.

Process of data cleaning

Physical Activity Behaviours

PALconnect, PALanalysis, and PALbatch were used for ActivPAL management, data visualisation and data processing (PAL Technologies). A valid day was considered to be a day that the student wore the ActivPAL for 24 hours (1440 minutes) and had no non-wear time (0 minutes). PALanalysis weekly overviews have been consulted to determine whether the students removed the ActivPAL during the week (see Figure 4). The day the ActivPAL was placed and the day it was removed were not included in the analyses. Among adolescents the number of monitoring days needed to achieve an adequate reliability (≥ .80) ranges from 4 to 9 days. Because of this inconsistency, a 7-day monitoring protocol for the current study seemed like a sensible choice (Trost, Mciver, & Pate, 2005). In addition, physical activity levels in adolescents differ between weekdays and weekend days (Jago, Anderson, Baranowski, & Watson, 2005), a trend that was also found in the current dataset (see Results of Data Cleaning). Since the focus of the current project was on PAB during school hours, it was decided to include only data from weekdays in the further analyses. To determine whether there were any statistically significant differences in PAB between the days of the week a one-way independent ANOVA was performed. Post hoc comparisons using a Bonferroni correction indicated which specific weekdays PAB means differed significantly. PAB were calculated in minutes per day by calculating the mean of all valid weekdays. This procedure was necessary because the number of ActivPAL-worn days ranged from 1 to 12 days.

Trail Making Test

A negative value on TMTB-A means that the participant spent longer on Part A (connecting the dots of ascending numbers) than on part B (connecting the dots in ascending order, alternating between numbers and letters). These negative scores were excluded from further analysis as they do not represent (set-) shifting.

Digit Span Backward test

The maximum digit span was adjusted if the objective or subjective observations indicated an incorrect execution of (part of) the test. This can result in the exclusion of a participant.

Colour-Shape Task

The method of data processing is based on Miyake et al. (2004). First, data were filtered on correctness by chance. This means that participants who have rounds with 50% or less correct answers (32 out of 64) were excluded. Next, all congruent trials in inhibitions-tasks were excluded from the data. Congruent trials have identical stimuli, require the same response, and thus do not require inhibition. Then, trials with RTs below 170 milliseconds and above 5000 milliseconds were excluded from analyses. RTs below 170 milliseconds indicate that the participant did not take in the stimulus and probably just pressed a random response key (Woods, Wyma, Yund, Herron, & Reed, 2015). The high limit of 5000 milliseconds is based on a study of Miyake, Emerson, Padilla and Ahn (2004). Finally, all interpersonal data (mean < -3 *SD* or > +3 *SD*) were eliminated. These data can be viewed as outliers and might influence the mean of the participant considerably. A negative value on inhibition cost means that the participant spent longer on round 1 and 2 (shape-test and colour-test) than on round 3 and 4 (shape-inhibition-task and colour-inhibition-task). These negative scores were excluded from further analysis as they do not represent inhibition cost.

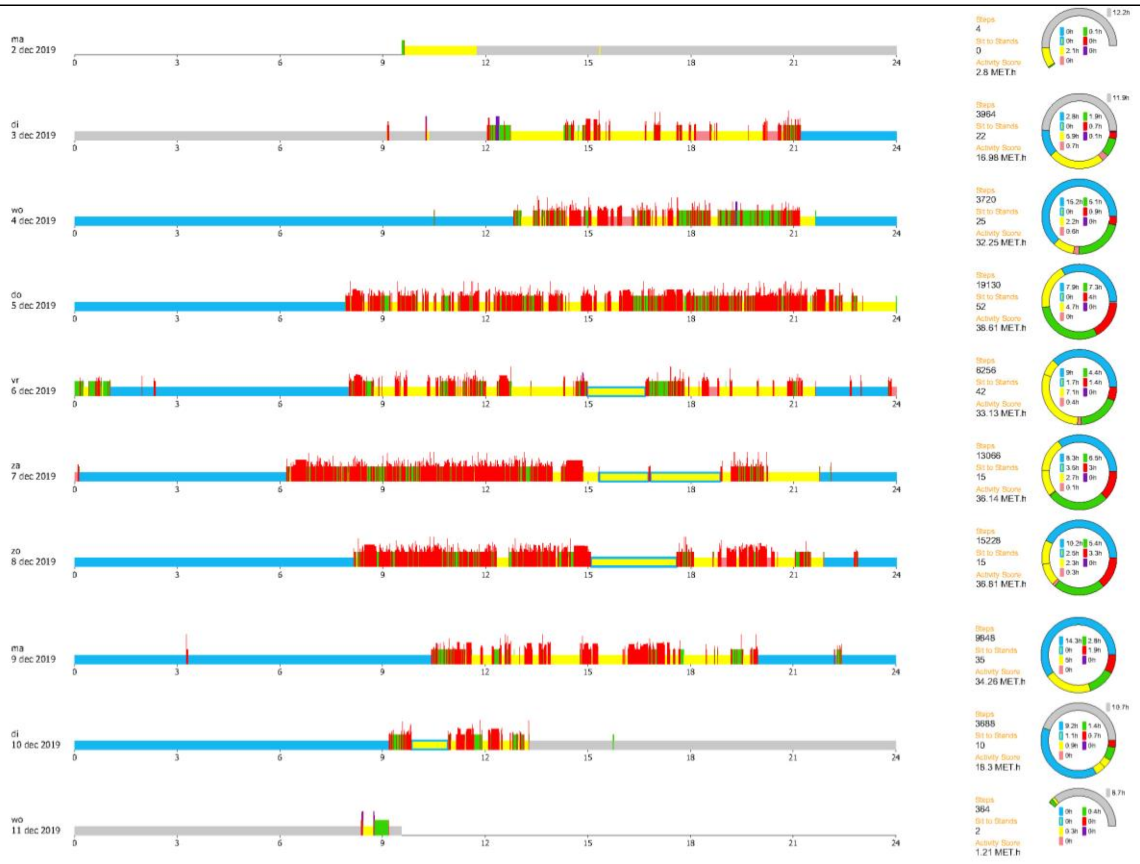

Figure 4. Weekly overview of the ActivPAL accelerometer data. This student wore the ActivPAL six entire days (1440 min/day), from Tuesday to Tuesday.

Covariates

Two covariates were included in this study. Sex (male or female) was used as a covariate as Wickel (2017) found inhibition to be negatively associated with moderate PA and MVPA specifically among boys. BMI was used as a covariate as Crova et al. (2014) found 1) better inhibition in higher- than lower-fit children, and 2) that improvement in inhibition after an enhanced physical education programme was more obvious in overweight children (BMI >25) than in lean children. BMI was calculated by dividing the weight in kilograms (one decimal) by the height in meters (one decimal) squared. BMI was then categorised (coded as 1 = underweight, 2 = healthy weight, 3 = overweight, and 4 = obese), following the BMI-for-age percentile as BMI for children and adolescents aged 2 to 19 years varies by age and sex (Voedingscentrum, n.d.).

Procedure

After approval of the Research Ethics Committee of the Open University of the Netherlands (cETO; U2017/00519/FRO), several schools were approached. At the three cooperating schools all students were informed in the classroom face-to-face by the research staff on the PHIT2LEARN project and its relevance for VET students. They received an information letter with details about the study by which they were also invited to participate. This letter included a reminder that participation was voluntary, that they could withdraw at any time, and that their personal data would be anonymized and kept confidential. After a reflection period of two weeks, all students were asked to sign an informed consent and hand this over to the researchers to confirm study participation. In the case of students aged under 16, consent was also obtained from primary caregivers. After receiving the informed consents, a first test session was planned in which participants filled in an online questionnaire and executed the executive tests in the following order: DSB, TMT, and CST. Afterwards, their weight and height were measured in light clothing without shoes. In another test session, planned one or two days later, SP was tested by MT.

The executive tests as well as the test for SP were conducted while participants were sitting behind a desk. All tests were performed on a laptop connected to the internet, except for the DSB which was carried out on paper. All classmates were placed in one classroom, as they were used to. To ensure that the tests were made independently and in silence, participants were supervised by a teacher and part of the research staff. One week later a catch-up moment for all tests was scheduled for those who couldn't attend the first sessions due to illness or other absence reasons. The following week ActivPALs were attached to the thigh of the participant to measure PAB. They were removed after seven days.

Analyses

Analyses were performed with SPSS for Windows (version 24). The level of significance was $p \leq .05$. First, scores on SP, EF, and PAB were calculated according to the described procedures (see Data cleaning). A data screening was performed to ensure that all data were usable, reliable, and valid. The Shapiro-Wilk test was used for assessing normality, as it is more appropriate for small sample sizes (< 50) than the Kolmogorov-Smirnov Test. Not normally distributed data were subjected to a log transformation (LG10) to correct for positive skewness and positive kurtosis (TMTB-A, BMI, LPA, sit-stand). Descriptive statistics for all variables were reported before transformation. Participants with missing data in one or more test were only removed from the relevant analysis to keep the sample as large as possible.

To measure simple correlations between PAB measures and the respective outcome measures Pearson's correlation was used for data that were normally distributed, whereas Kendall's tau was used in case the assumptions for Pearson were not met (DSB, TMTA, CST). A correlation coefficient of +1 indicated a perfect positive relationship, a coefficient of -1 indicated a perfect negative relationship, and a coefficient of 0 indicated no linear relationship at all. In the case of a positive or negative correlation between PAB or a covariate (sex, BMI), and one of the learning outcomes, data were analysed by a multiple linear regression analyses involving three steps.

First, associations between covariates and the SP or EF outcome measure were modelled (Step A). Continuous variables and covariates were transformed into z-scores before they were entered in the multiple regression. Sex was entered as a dummy variable (coded as 0 = male, 1 = female). This step made it possible to control the results for possible confounding effects of the covariates. Then PAB were added to the model (Step B). This step made is possible to investigate the added explained variance of PAB to the model. Then, data were explored for potential interaction effects of covariates on the associations between PAB and SP or EF measures. In the last step a moderation analysis was done by adding interaction effects (see Figure 5). Interaction terms were calculated between the z-scores of PAB and BMI, and PAB and the dummy variable of sex, then added to the model (Step C).

To test the assumptions of multiple regression, the normal P-P plots were consulted to check for a normal distribution of the residuals, scatterplots were conducted to check for homoscedasticity, and the Variation Inflation Factor (VIF) were checked for absence of multicollinearity. In the reported results of the multiple regression analyses outliers (>2 standard deviations) were excluded.

In the end, to examine the generalizability of the study sample to the total study population a Pearson's chi-square test was performed to examine the differences in sex between the study sample and the remaining population. For the same reason all normally distributed variables (age, BMI, AMN, TMTB-A, and CST_latency) were analysed by an independent T-Test and not normally distributed variables (DSB, TMTA, and CST_positive) were analysed by a Mann-Whitney test.

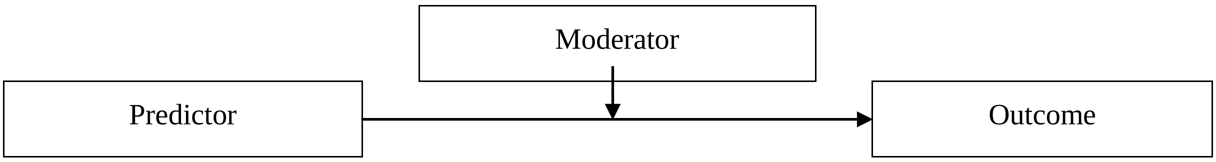

Figure 5. Conceptual moderation model.

Results

Results of data cleaning

An ANOVA showed no statistically significant differences in all PAB measures between the weekdays (SB (F(4,110) = .393, p = .814)), (LPA (F(4,110) = .881, p = .478)), (MVPA (F(4,110) = .756, p = .556)), and (sit-stand transitions (F(4,110) = .854, p = .494)). It was therefore decided that data from a minimum of two valid ActivPAL wearing weekdays (1440 min/day) were needed for a participant (N = 31) to be included in the analyses and to calculate average PAB scores per weekday. In this way, the sample has been kept as large as possible. A second ANOVA with 29 participants, after removing 2 participants who did not participate in the tests, did not lead to other results than with 31 participants and consequently did not affect the choice for weekdays.

Participants

The student population from the approached classes consisted of 203 students in total. Eventually, 165 out of these 203 students signed an informed consent of which 79 agreed to wear an ActivPAL. Only 31 out of the 79 participants who wore the ActivPAL, wore it for at least two valid weekdays (1440 min/day). In addition, two participants did not participate in the tests for EF and SP. These participants were excluded from further data analyses. Therefore, the final sample size consisted of 29 participants. The reasons for non-participation at each stage are displayed in the flow chart (see Figure 6). Participants not having participated in one or more test or with data excluded in the process of data cleaning were only removed from the relevant analysis to keep the sample as large as possible (AMN (N = 3), TMTB-A (N = 9), DSB (N = 1), and CST (N = 7).

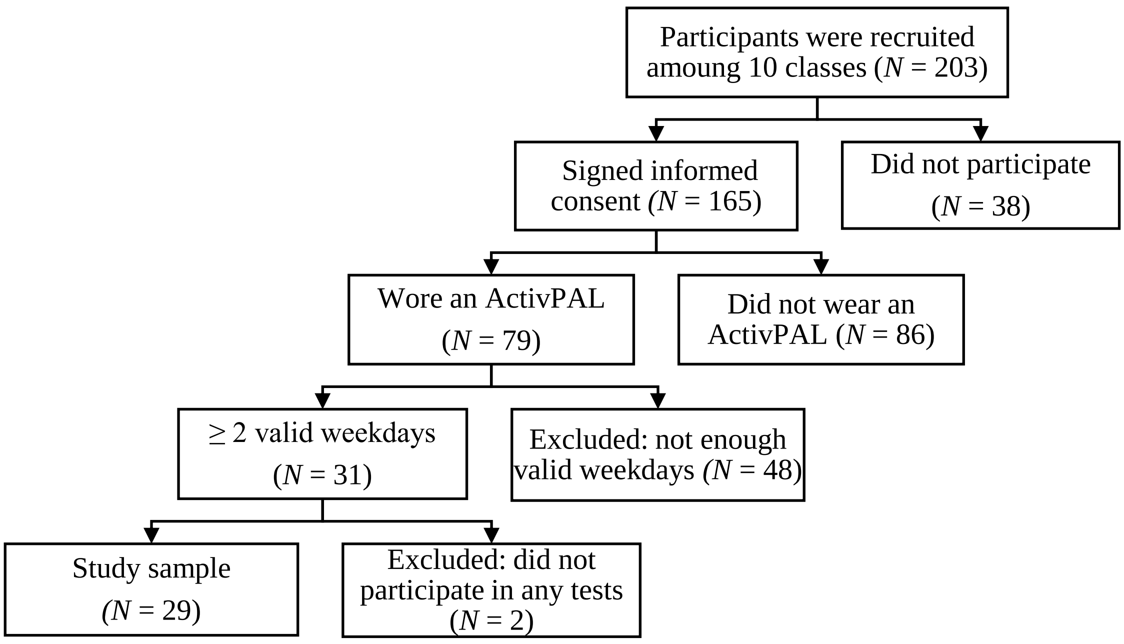

Figure 6. Flow chart with the reasons for non-participation at each stage.

Characteristics of the study sample

Participants had a mean age of 18.4 years (*SD* = 2.2), and mean weight of 73.9 (*SD* = 24.0). Using the Voedingscentrum (n.d.) classification of BMI, 3.4% of the participants were underweight, 48.3% had a healthy weight, 24.1% was overweight, and 24.1% was obese. The students spent on average 9.2 hours sitting, 4 hours on LPA and approximately 35 minutes on MPVA. They switched between these PA behaviours for about 42 times. On average, students scored 19 (out of 39) on the mathematics test (school performance). Students had a mean RT of ≈ 55 seconds on TMTA (trail making latency) and ≈ 25 seconds on TMTB-A (shifting). On average, students DSB (updating) was 4 (out of 8). Students had a mean RT of ≈ 0.5 seconds on CST_latency (stimulus-reaction latency) and ≈ 0.07 seconds on CST_positive (inhibition). The descriptive statistics for all study variables are presented in Table 1.

Table 1

Description Statistics of the Study Sample

	Male (*N* = 11; 37.9%)	**Female (*N* = 18; 62.1%)**	**Total (*N* = 29)**
Age (years)	17.6 (1.3)	18.9 (2.6)	18.4 (2.2)
BMI	27.17 (8.61)	25.38 (4.2)	26.06 (6.25)
Underweight	0.0 %	5.6 %	3.4 %
Healthy Weight	54.5 %	44.4 %	48.3 %
Overweight	9.1 %	33.3 %	24.1 %
Obese	36.4 %	16.7 %	24.1 %
Physical Activity Behaviours			
SB	568.53 (127.54)	546.29 (122.88)	554.73 (122.88)
LPA	243.07 (67.61)	238.04 (112.32)	239.95 (96.43) [b]
MVPA	37.69 (26.57)	32.86 (23.57)	34.69 (24.40)
Sit-to-stand transitions	46.38 (17.70)	40.78 (11.88)	42.90 (14.33)
School Performance			
Mathematics	19.60 (7.95)	18.63 (5.30)	19.00 (6.31)
Numbers	5.60 (2.67)	5.06 (1.77)	5.27 (2.13)
Proportions	6.80 (3.26)	6.88 (1.75)	6.85 (2.38)
Measurements & geometry	4.10 (2.42)	3.06 (1.44)	3.46 (1.90)
Relations	3.10 (1.29)	3.63 (1.78)	3.42 (1.60)
Executive Functioning			
Trail making latency	55940.82 (17536.60)	55930.61 (16555.00)	55934.48 (16619.84)
Shifting	17074.14 (17796.42)	29304.23 (20101.60)	25023.70 (19774.69)
Updating	4 (0)	4 (1)	4 (1)

Stimulus-reaction latency	465.31 (59.25)	547.88 (91.01)	516.56 (89.14) [a]
Inhibition	49.78 (37.70)	80.19 (61.82)	71.90 (57.10)

Note. Mean (SD), Age in years, BMI = body mass index classification via Voedingscentrum (n.d.), SB = minutes of sedentary behaviour per day (mean), LPA = minutes of light physical activity per day (mean), Sit-to-stand transitions per day (mean), MVPA = minutes of moderate-to-vigorous physical activity per day (mean), Executive functioning scores in milliseconds.
[a] Statistically significant difference for sex at $p < .05$.
[b] Statistically significant difference for BMI at $p < .05$.

The association between physical activity behaviours and school performance

No significant correlations were found between any of the PAB measures and any of the SP measures, with the exception of the mathematical subdomain Numbers. Numbers showed a significant correlation with MVPA ($r = .397$, $p = .044$) (see Table 2). Multiple linear regression analysis revealed that possible covariates (sex and BMI) were overall not significantly associated with Numbers (Table 3, Step A). MVPA was no longer significantly associated with Numbers after correction for sex and BMI (Table 3, Step B) and a significant interaction effect between MVPA and sex or BMI was not found (Table 3, Step C). The normal P-P plots of the multiple regression analyses indicated a normal distribution of the residuals and the scatterplots showed homoscedasticity. Multicollinearity was absent (Variation Inflation Factor (VIF)).

Table 2

(Bivariate) Correlation Analysis between SP and PAB

		Physical Activity Behaviours			
		SB	LPA	MVPA	Sit-to-stand transitions
School Performance					
Mathematics	Correlation coefficient	.072	-.048	.172	-.186
	Sig. (2-tailed)	.726	.814	.402	.363
	N	26	26	26	26
Numbers	Correlation coefficient	.138	.110	.397	-.029
	Sig. (2-tailed)	.500	.592	.044*	.889
	N	26	26	26	26
Proportions	Correlation coefficient	.006	-.121	-.056	-.204
	Sig. (2-tailed)	.978	.557	.786	.317
	N	26	26	26	26
Measurements & geometry	Correlation coefficient	.058	.074	.165	-.065
	Sig. (2-tailed)	.777	.721	.420	.752

	N	26	26	26	26
Relations	Correlation coefficient	.023	-.245	.035	-.313
	Sig. (2-tailed)	.913	.228	.863	.120
	N	26	26	26	26

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3

Multiple Linear Regression Analyses on MVPA, Numbers and Covariates

	Numbers		
	Δ*R*^{2}	**Adj. *R*^{2}**	**β**
Step A	.104	.026	
Sex			.111
BMI			-.298
Step B	.220	.114	
MVPA			.353
Step C	.353	.191	
Sex x MVPA			.123
BMI x MVPA			-.402

Note. Step A = model including covariates; Step B = model including Step A and MVPA; Step C = model including Step B and potential interaction effects, β = standardized regression coefficients.

The association between physical activity behaviours and executive functioning

No significant correlations were found between PAB measures and any of the EF measures (see Table 4). Multiple linear regression analysis revealed that sex and BMI were overall significantly associated with stimulus-reaction latency (Table 3, Step A). Besides the fact that no PAB measures were significantly associated with stimulus-reaction latency (Table 3, Step B.1-B.2), no significant interaction effects were found between any PAB measures and sex, or any PAB measured and BMI (Table 3, Step C.1-C.2). The normal P-P plots of the multiple regression analyses indicated a normal distribution of the residuals and the scatterplots showed homoscedasticity. Multicollinearity was absent (Variation Inflation Factor (VIF)).

Table 4

(Bivariate) Correlation Analysis between PAB and SP

		Physical Activity Behaviours			
		SB	LPA	MVPA	Sit-to-stand transitions
Executive Functioning					
Trail making latency	Correlation coefficient	-.161[a]	.059[a]	-.202[a]	-.066[a]
	Sig. (2-tailed)	.404	.762	.294	.736
	N	29	29	29	29
Shifting	Correlation coefficient	-.221	.174	.268	-.027
	Sig. (2-tailed)	.350	.463	.253	.909
	N	20	20	20	20
Updating	Correlation coefficient	.178[a]	-.089[a]	.197[a]	-.109[a]
	Sig. (2-tailed)	.364	.652	.315	.581
	N	28	28	28	28
Stimulus-reaction latency	Correlation coefficient	-.100	.073	.109	.005
	Sig. (2-tailed)	.607	.705	.574	.979
	N	29	29	29	29
Inhibition	Correlation coefficient	.060[a]	-.139[a]	.062[a]	-.169[a]
	Sig. (2-tailed)	.792	.538	.783	.452
	N	22	22	22	22

Note. a. Kendall's Tau.

Table 5

Multiple Linear Regression Analyses on PAB, Stimulus-reaction Latency and Covariates

	Stimulus-reaction Latency		
	ΔR^2	**Adj. R^2**	**β**
Step A	.321*	.269	
Sex			-.487*
BMI			.336*
Step B.1	.417*	.290	
SB			.205
MVPA			.345
Sit-stand transitions			.037
Step B.2	.321*	.240	

LPA			-.025
Step C.1	.548	.256	
Sex x SB			-.252
Sex x MVPA			-.276
Sex x sit-stand transitions			-.052
BMI x SB			.003
BMI x MVPA			-.102
BMI x sit-stand transitions			.271
Step C.2	.336	.225	
Sex x LPA			.115
BMI x LPA			.080

Note. Step A = model including covariates; Step B.1-B.2 = models including Step A and PAB; Step C.1-C2 = models including Step B and potential interaction effects, β = standardized regression coefficients.
**p* = <.05

Conclusion and discussion

Key results

The main goal of the current study was to investigate the association between objectively measured physical activity behaviours and learning outcomes in VET students. No significant associations between any of the PAB measures and any of the SP were found, even after correcting for sex and BMI. Also, no significant associations between any of the PAB measures and any of the EF measures were found, even after correcting for sex and BMI. This implies that VET students who are more physically active do not necessarily have better learning outcomes than their classmates who are less physically active.

Interpretation

The amounts of PAB found in this study do not alleviate the concerns with respect to the increase of adolescent's inactivity described by Dumith et al. (2011) and Mitchell et al. (2012), and its health risks (Katzmarzyk et al., 2009; Owen et al., 2009). With only 35 minutes of MVPA, recommendations for adults (≥150 min/week) are met in this study (World Health Organization, 2010). VET students however, hover between guidelines because of their age. Recommendations for children and youth are far from being met (60 min/day of MVPA). Therefore, there is reason to advocate for a more active lifestyle in VET students.

The relation between sedentary behaviour and physical activity, and school performance and executive functioning in VET however is an underexplored area of research. The current study has unfortunately only been able to contribute to this area to a very limited extent. The hypotheses based on findings in the theoretical framework could not be confirmed or falsified. This is due to the fact that no significant associations were found, even after correcting for sex and BMI.

The amount of PAB was not significantly associated with SP in VET students, and the expected positive association for the amount of MVPA and school performance (mathematics performance) based on a systematic review by Singh et al. (2018) was not found. The fact that no associations have been found may have several reasons. First, all four studies (Donnelly et al, 2009; Ericsson, 2008; Gao, Hannan, Xiang, Stodden, & Valdez, 2013; Telford et al., 2012) that were included by Singh et al. (2018) had a longitudinal design. They all included maths performance assessed MVPA intervention programmes with a minimum of three sessions per week and a minimal programme duration of two school years. This could mean that an association with maths performance can only be found when MVPA is increased for a longer period of time. Second, in all studies reported by Singh et al. (2018), only a total score for mathematics was included. It is therefore not possible to establish whether there was a significant association for the subdomain Numbers, a trend that was found in the current dataset.

The amount of PAB was also not significantly associated with EF in VET students in the current study. The covariates sex and BMI played no significant role in this, although this was expected based on research by Wickel (2017) and Crova et al. (2014), respectively. Also, the expected outcomes based on Wickel (2017) have not been confirmed, as no significantly positive associations between the amount of SB and executive functioning, and no negative associations between the amount of LPA and MVPA and updating, and the amount of LPA and shifting and inhibition, were found. Even the non-significant associations did not point in this specific direction. This is surprising since part of Wickel's (2017) study, were cross-sectional associations among PAB with executive function are examined in early adolescence (15 years old), is very similar in design to the current study. The instruments used are also valid and reliable for measuring EF. Inhibition was assessed with a modified version of the impulse control subscale adopted from the Weinberger Adjustment Inventory (WAI). Working memory (i.e., updating) was evaluated using Operation Span (OSPAN). The Tower of London test was used for measuring fluid intelligence (i.e., shifting). The fact that no associations have been found may have several reasons. First, unlike the current study, participants in Wickel’s study completed executive function tasks within a laboratory environment. This non-natural situation may have affected their results. Second, the number of participants in Wickel's study (N = 403) is significantly larger than that in the current study (N = 29). The current study does therefore not strengthen the linkage between PAB and executive functioning that has been demonstrated by a growing body of research with children (De Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018;

Diamond & Lee, 2011; Fedewa & Ahn, 2011; Tomporowski, Davis, Miller, & Naglieri, 2008). First, this can be explained by the fact that all four meta-analyses mentioned included only studies that had a longitudinal design, such as the most recent study by De Greef et al. (2018). This study showed that longitudinal PA programs have a positive effect on EF. This could mean that an association with EF can only be found when PA is increased for a longer period of time. Second, population differences may have contributed to a different result in the current study as the meta-analyses targeted children up to 16 years old. Sibley and Etnier (2003) in fact found a stronger relationship between PA and cognitive performance for children in the age ranges of 4-7 (early primary school) and 11-13 years (early secondary school), compared to the age ranges of 8-10 (late primary school) and 14-18 years (late secondary school up to further education). The latter is relevant to the current study, although it does not demonstrate the association between PA and EF in this age group. Several possible reasons for the differences between the age groups were mentioned by Sibley and Etnier (2003).

The finding that the association between PA and cognition was larger for early primary school children was not surprising, as research has suggested that PA may be especially important to the cognitive development of very young children (Leppo, Davis, & Crim, 2000; Piaget, 1968; Pica, 1997). With regards to the larger effect for early secondary school children, it has been suggested that this is related to social anxiety that is uniquely evident for 11 to 13-year-olds. These children are starting to value the opinions of their peers more, and are going through physical changes that are associated with puberty (Pangrazi & Darst, 2002). This could mean that for this age group PA benefits cognitive performance indirectly by increasing self-esteem and/or decreasing anxiety. However, Sibley and Etnier (2003) acknowledged that their meta-analysis was limited in that the methodological accuracy of many studies was questionable and only nine out of 44 studies evaluated were reported in peer-reviewed journals.

Generalisability

The descriptive statistics for all study variables are presented in Appendix A, Table 1. First, except for sex ($\chi(1) = 4.127$, $p = .042$; see Appendix B, Table 1) no significant differences were found between the study sample ($N = 29$) and the remaining population ($N = 133$) on characteristics, SP, and EF (see Appendix B, Table 2-3). Therefore, the study sample was representative for the total study population. However, results cannot be generalized to the entire Dutch VET student population because only level 2 students were included in this study. They represent only 10% (51800) of the total number of VET students (500.000) (Ministerie van Onderwijs, Cultuur en Wetenschap, Dienst Uitvoering Onderwijs, Centraal Bureau voor de Statistiek, n.d.). Second, a selection bias might have been present in this study because participants were allowed to choose whether they wanted to wear an ActivPAL (no random sampling). Students who are relatively more physical active, and therefore possibly more interested in their own activity pattern were perhaps more inclined to wear the ActivPAL compared to students who are more physical inactive. Even though the BMI of the study sample (M = 26.06) did not significantly differ from the remaining population (M = 23.97), it cannot be concluded that the study sample was more active since the relationship between physical activity and BMI is not straightforward (Ball, Owen, Salmon, Bauman, & Gore, 2001).

Strengths and limitations

The major strength of the present study is that it fills a gap in the extant literature on physical activity and learning outcomes through its student population attending vocational education and training (VET). Additionally, physical activity behaviours were measured objectively using the ActivPAL, which has been assessed to be a reliable and valid instrument to investigate physical activity in adolescents (Dowd et al., 2012) and adults (Dahlgren et al., 2010).

Nevertheless, this study had some limitations. First, the cross-sectional nature of this study makes it impossible to determine causal relations of both main and interaction effects. Therefore, longitudinal studies are needed to find out whether PAB influences learning outcomes. Second, the response rate (students who were willing to wear the ActivPAL) was quite low. From classroom experiences, it can be concluded that class dynamics, social pressure, and concerns about privacy played a major role in the decision to wear the ActivPAL. This should be taken into account in follow-up research with preferably a larger sample. As a result, the minimum sample size of 59 participants to achieve adequate power was not reached. Third, students did not keep a diary describing atypical schooldays (i.e., weekdays without school lessons). Consequently, days of sickness or injury were included. Also, their schedule was not included in this research, so that it is not clear whether they are at home or at school. It was therefore not possible to make a distinction between the relationship of PAB at school and outside of school on learning outcomes, as was done for SB by Carson et al. (2016). Forth, comments can be made about the instruments used to measure executive functioning and the conditions under which the tests were carried out. Specifically, the paper version of the DSB-test made it possible for students to write from right to left during the test. Notes made by the observers (objective during the scoring and subjective during measurement and scoring) led to the exclusion of these answers, as these results did not reflect their ability to ‘update’ their working memory. Unfortunately, these notes were not equally consistent in all measurements. In future studies it would be advised to take all tests in smaller groups or students, so that observers can keep a close eye on the participants, or use an online version of the test that enables a reverse fill in. In this respect, it should be noted that test conditions were realistic and therefore the most representative for VET schools, but possibly not the most beneficial for the test results. It was regularly restless in the classrooms by chatter and scraping sounds from tables and chairs. Non-auditory tasks such as short-term memory, reading and writing are impaired by noise (Klatte, Bergström, & Lachmann, 2013). Additionally, both CST and TMT resulted in negative scores. This could be due to the fact that the task was only automated after the first part of the tests (CST round 1 and 2; TMT-A), and not already after the practice rounds. In future studies, it would be worthwhile to consider extending these practice rounds. Fifth, the number of researchers (up to 5) the students came into contact with might have made it difficult for them to build a bond. According to Lesterhuis (2010) the use of the affective strategy for teachers in VET level 1 or 2 is essential to achieve goals. In the first place it is about motivating students. For VET level 1 or 2 students, confidence in the teacher, mutual respect and clarity about what is expected of them is essential to be motivated to come to school and cooperate in class. Perhaps with better bonding, a higher response rate could have been achieved. Considering these limitations, results must be interpreted with caution.

Conclusion

Adapting a school environment, whether by introducing sit-stand desks or other interventions, can potentially promote a more active lifestyle (Hinckson et al., 2016; Minges et al., 2016; Sherry et al., 2016)). However, VET schools should not bet everything on promoting physical activity, because the evidence of a positive association between physical activity behaviours and learning outcomes in VET students is not yet sufficient. Any intervention that is introduced has to be researched carefully to ensure that the proposed solution balances physical activity behaviours with learning outcomes. In any case, VET students are the employees of the future who will need to be educated towards vital citizenship (Ministerie van Onderwijs, Cultuur en Wetenschap, 2019). Creating awareness about the risks of sedentary behaviour and the opportunities for physical activity should start early.

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Appendix A

Descriptive statistics

Table 1

Descriptive Statistics of Study Sample, Remaining Population and Total Study Population.

	ActivPAL (*N* = 29) (Male = 11 / Female = 18)				**Remaining population* (*N* = 133)** (Male = 78 / Female = 55)				**Total (*N* = 162)** (Male = 73 / Female = 89)			
	Mean	*SD*	Median	*SE*	Mean	*SD*	Median	*SE*	Mean	*SD*	Median	*SE*
Age (years)	18.4	2.2	17.9	.4	18.4	2.0	17.9	.2	18.4	2.0	17.9	.2
BMI	26.06	6.25	24.49	1.16	23.97	5.33	22.85	.48	24.37	5.56	23.19	.45
Underweight	3.4 %				13.9 %				11.9 %			
Healthy Weight	48.3 %				51.6 %				51.0 %			
Overweight	24.1 %				18.0 %				19.2 %			
Obese	24.1 %				16.4 %				17.9 %			
Physical Activity Behaviours												
SB	554.73	122.88	576.31	22.82								
LPA	239.95 [b]	96.43	217.28	17.91								
MVPA	34.69	24.40	29.02	4.53								
Sit-to-stand transitions	42.90	14.33	40.50	2.66								
School Performance												
Mathematics	19.00	6.31	18.50	1.24	18.65	7.81	18.00	.71	18.71	7.55	18.00	.62
Numbers	5.27	2.13	5.00	.42	5.25	2.61	5.00	.24	5.25	2.52	5.00	.21
Proportions	6.85	2.38	6.50	.47	6.65	2.75	6.00	.25	6.68	2.68	6.00	.22
Measurements &	3.46	1.90	3.50	.37	3.55	1.91	4.00	.17	3.53	1.90	4.00	.16
Relations	3.42	1.60	3.50	.31	3.20	1.80	3.00	.16	3.24	1.76	3.00	.14
Executive Functioning												
Trail making latency	55934.4	16620.8	50216.0	3086.23	61139.0	19847.9	55856.5	1754.24	60177.7	19348.3	54807.0	1544.17
Shifting	25023.7	19774.6	19936.5	4421.76	24719.2	27697.0	15228.5	3021.99	24777.7	26273.8	15544.0	2576.37
Updating	4	1	4	0	4	1	4	0	4	1	4	0
Stimulus-reaction latency	516.56 [a]	89.14	508.72	16.55	505.79	83.55	489.74	7.39	507.09	84.44	494.05	6.74
Inhibition	71.90	57.10	60.23	12.17	66.12	42.92	55.96	4.71	67.33	46.01	57.88	4.49

Note. *Age* in years, BMI = body mass index classification via Voedingscentrum (n.d.), SB = minutes of sedentary behaviour per day (mean), LPA = minutes of light physical activity per day (mean), Sit-to-stand transitions per day (mean), MVPA = minutes of moderate-to-vigorous physical activity per day (mean), Executive functioning scores in milliseconds. * Contains participants ($N = 48$) who wore the ActivPAL, but for less than two valid weekdays (1440 min/day). [a] Statistically significant difference for sex at $p < .05$. [b] Statistically significant difference for BMI at $p < .05$.

Appendix B

Generalisability to remaining population on SP and EF

Table 1

Pearson's Chi-square Test of Independence to Examine the Differences in Sex between the two Groups

			ActivPAL	Remaining population*	Total
Sex	Male	Count	11	78	89
		% within What's your gender?	12,4 %	87,6 %	100,0 %
		% within ActivPAL	37,9 %	58,6 %	54,9 %
		% of Total	6,8 %	48,1 %	54,9 %
	Female	Count	18	55	73
		% within What's your gender?	24,7 %	75,3 %	100,0 %
		% within ActivPAL	62,1 %	41,4 %	45,1 %
		% of Total	11,1 %	34,0 %	45,1 %
Total		Count	29	133	162
		% within What's your gender?	17,9 %	82,1 %	100,0 %
		% within ActivPAL	100,0 %	100,0 %	100,0 %
		% of Total	17,9 %	82,1 %	100,0 %

Note. * Contains participants (*N* = 48) who wore the ActivPAL, but for less than two valid weekdays (1440 min/day).

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.127[a]	1	.042		
Continuity Correction[b]	3.333	1	.068		
Likelihood Ratio	4.121	1	.042		
Fisher's Exact Test				.063	.034
Linear-by-Linear Association	4.102	1	.043		
N of Valid Cases	162				

Note.
[a]. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 13,07.
[b]. Computed only for a 2x2 table

Table 2

Independent Samples T-Test to Examine the Differences in Age, BMI, AMN, TMTB-A and CST_latency between the two Groups

	Levene's Test for Equality of Variances		T-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Age	.235	.629	-.056	160	.956	-.00048	.00869	-.01765	.01668
			-.053	39.338	.958	-.00048	.00909	-.01887	.01790
BMI	.049	.825	1.832	149	.069	.03520	.01921	-.00276	.07316
			1.763	40.569	.085	.03520	.01997	-.00514	.07554
AMN_total	3.697	.056	.215	146	.830	.35246	1.63685	-2.88253	3.58744
			.247	43.048	.806	.35246	1.42575	-2.52275	3.22767
AMN_G	3.208	.075	.043	146	.966	.02333	.54685	-1.05743	1.10409
			.049	42.670	.961	.02333	.47932	-.94353	.99019
AMN_M	2.198	.140	.342	146	.733	.19861	.58016	-.94799	1.34521
			.376	40.540	.709	.19861	.52847	-.86903	1.26626
AMN_VB	.252	.617	-.213	146	.832	-.08764	.41181	-.90152	.72624
			-.213	36.515	.832	-.08764	.41109	-.92096	.74567
AMN_VH	.704	.403	.573	146	.568	.21816	.38100	-.53482	.97114
			.616	39.538	.541	.21816	.35413	-.49782	.93413
TMTBA	1.298	.257	.883	102	.379	.12331	.13970	-.15379	.40041
			1.057	37.285	.297	.12331	.11666	-.11300	.35962
CST_latency	.414	.521	.668	155	.505	11.61674	17.39646	-22.74800	45.98148
			.641	39.908	.525	11.61674	18.12533	-25.01855	48.25203

Note. Equal variances assumed / equal variances not assumed. AMN_total = total mathematics score, AMN_ G = Numbers, AMN_M = Proportions, AMN_VB = Measurements & geometry, AMN_VH = Relations.

Table 3

Mann-Whitney Test to Examine the Differences in DSB, TMTA, CST_positive between the two Groups

	Test Statistics[a]		
	DSB	TMTA	CST_positive
Mann-Whitney U	1558.000	1573.000	904.000
Wilcoxon W	8579.000	2008.000	4390.000
Z	-.496	-1.280	-.071
Asymp. Sig. (2-tailed)	.620	.201	.944

Note. [a] Grouping Variable: ActivPAL (The remaining population contains participants (N = 48) who wore the ActivPAL, but for less than two valid weekdays (1440 min/day)).